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Analysis of Different Sand Casting Defects in a Medium Scale Foundry Industry - A Review

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ABSTRACT: A defect in castings does not just happen. Casting defects are unusually not by accidents, they occur because some step in manufacturing cycle does not get properly controlled and somewhere something goes wrong. They are caused by wrong practice in one or more of the basic operations involved in the casting process as in the equipment used, or by the design of the part. A defect may be the result of a single clearly defined cause or a combination of factors, in which case necessary preventive measures are more obscure. If not controlled the rejection may be up to 50 also. Hence close control and standardization of all aspects of manufacturing techniques offers the best control against the occurrence of defects in castings. Normally castings also contain certain imperfections and discontinuity which contribute to a normal quality variation. Such imperfections are considered as defects when they affect the appearance or the satisfactory sound functioning of the casting. Defective casting offers ever-present problems to the foundry industry. Defective casting account higher losses to sand casting industry. Hence a systematic study can overcome the defects.

KEYWORDS: Casting, Casting defects, Casting Rejection, Cause and remedies, cause and effect diagram.

I. INTRODUCTION

A casting defect is an undesired irregularity in a metal casting process. Some defects can be tolerated while others can be repaired, otherwise they must be eliminated. A properly designed casting, a properly prepared mould and correctly melted metal should result in a sound casting. However, if proper control is not exercised a variety of defects may result in a casting. These defects may be because of following reasons

1. Improper pattern/tool design or lack of allowances,
2. Improper mould and core constituents,
3. Improper melting practice,
4. Improper pouring practice
5. Because of molding and core making materials.
6. Improper gating - risering system along with lack of feedaids.
7. Improper metal composition
8. Inadequate melting temp and rate of pouring.
9. Unskilled post melting treatment like shakeout, fettling etc.

Cause and effect diagrams were developed by Kauro Ishikawa of Tokyo University in 1943 and thus are often called Ishikawa Diagrams. They are also known as fishbone diagrams because of their appearance (in the plotted form). Cause and effect diagrams are used to list systematically the different causes that can be attributed to a problem (Effect-Y). By carrying out systematic analysis of casting rejection using Parato charts 82-20 principle a definite cause of defect can be known. A cause-and-effect diagram can aid in identifying the reasons why a process goes out of control and once its cause is identified then it can be overcome by various remedies.

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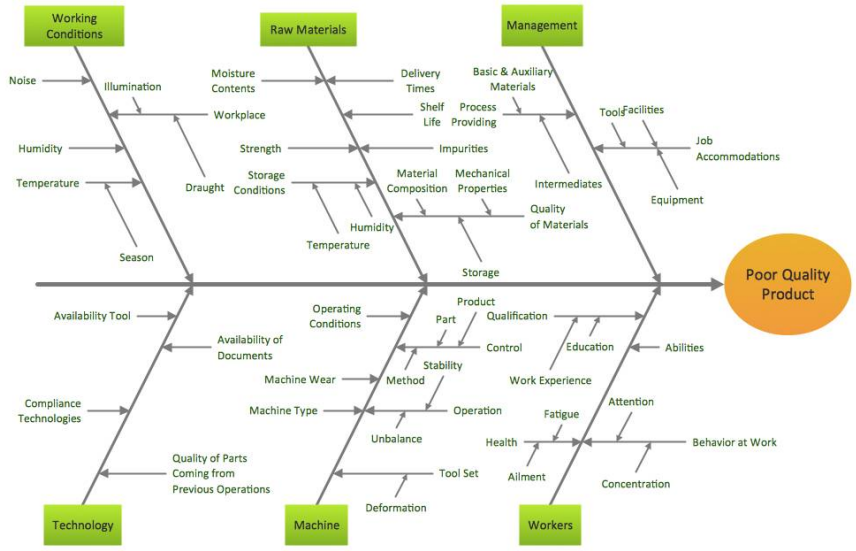

Fig. No. 1 Cause and effect diagram for a particular defect under study

The above fig.no.1 represents various causes like man, machine, method, material etc. leading to formation of particular type of defect/effect (Y) as blow hole, misrun etc.
In this paper a literature review is done focusing various defects in and casting process. From E resources different research papers were referred and studied. They are summarised as follows.

II. LITERATURE REVIEW

Table No.1 elaborates the recent research work published from various researchers and the summative conclusion from their research work in the field of casting defects and analysis.

Table No.1 Literature Review

Title of paper	Name of journal and year of publication	Author name	Summary from reference paper
Analysis of foundry defects and preventive activities for quality improvement of castings	METALURGIJA,42 , 2003	K. Siekak. Siekannskiski, S. Borkowski	Usage of cause and effect diagram permits in identifying areas especially subjected to defect formation. Statistical control tools as Pareto diagram directs to irrevocable separation of main nonconformances in defects.
Foundry quality control aspects and prospects to reduce scrap rework and rejection in metal casting manufacturing industries	Journal of Materials Processing Technology, 2006	T. R.Vijayaram, S. Sulaiman, A.M.S. Hamouda M.H.M. Ahmad	A careful monitoring with effective contribution of top to bottom employees in achieving Excellency in casting is needed in reducing the rejection and defects. In addition to the QC department, a scrap prevention team needs in improvement in quality casting
Effect of blow-holes on reliability of cast component	Sadhana Vol. 33, Part 6, December 2008,	B.N.RAO , Rajesh Ashokkumar	A study on the effect of defect on the reliability of a cast component, using the MPP-based univariate response surface approximation is presented.

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Title of paper	Name of journal and year of publication	Author name	Summary from reference paper
Analysis of Casting Defects and Identification of Remedial Measures – A Diagnostic Study	International Journal of Engineering Inventions ,October 2012	Dr.D.N.Shivappa, Mr, Rohit, Mr.Abhijit Bhattacharya	Diagnostic study reveals the contribution of the prominent defects in casting rejections are Sand drop, Blow hole, Mismatch, and Oversize. It is also noted that defects are frequently occurring at particular locations and a Systematic analysis should be carried out to understand the reasons for defects occurrence.
Minimization of Casting Defects	IOSR Journal of Engineering , May 2013	Achamyeleh A. Kassie, Samuel B. Assfaw,	DOE method such as Taguchi method can be efficiently applied for deciding the optimum settings of process parameters to have minimum rejection due to defects.
Investigation and analysis of cold shut casting defect and defect reduction by using 7 quality control tools	International Journal of Advanced Engineering Research and Studies, July-Sept 2013	B.R. Jadhav, Santosh J. Jadhav	A systematic approach to find the root cause of one of the major defects is needed.
A development of quality in casting by minimizing defects	International Journal of Recent Research in Civil and Mechanical Engineering ,April 2014	Prasan Kinagi, Dr. R.G Mench	Design of experiment and FMEA techniques are combined to analyze casting defects. Casting Defects can be minimized with optimal level settings of process parameters.Pareto principle is used to identify and evaluate different defects and causes for these defects responsible for rejection of components at different stages of manual metal casting operations. The correct identification of the casting defect at initial stage is very useful for taking remedial actions.
Review on Analysis of Foundry Defects for Quality Improvement of Sand Casting	International Journal of Engineering Research and Applications, March 2014	Sunil Chaudhari Hemant Thakkar	Modern method of casting components using various software and simulation technique is really a boost for casting quality and improvement in casting yield.
Defects, Causes and Their Remedies in Casting Process: a review	International Journal of Research in Advent Technology, March 2014	Rajesh Rajkolhe, J. G. Khan	Here a review is made for causes and their remedies These will help to QC department of foundry for analysis of casting defect.
Investigation and analysis of metal casting defects and defect reduction by using quality control tools	International Journal of Mechanical and Production Engineering, April 2014	Aniruddha Joshi, L.M.Jugulkar	CED methodology is easy to understand causes of defect production. Some easily possible main remedies are followed hence it minimizes the defects up to more percentage. In a manual foundry Pareto principle and cause effect diagram are used to identify and evaluate different defects and causes for these defects responsible for rejection of components.
Casting defects analysis in foundry and their remedial measures with industrial case studies	IOSR Journal of Mechanical and Civil Engineering , Nov. - Dec. 2015	Avinash Juriani	Here by using cause and defect analysis concept the various causes and remedial measures are suggested. This study will be highly useful in reducing casting defects in

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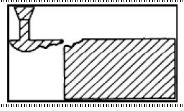
Title of paper	Name of journal and year of publication	Author name	Summary from reference paper
			foundries.
Quality Improvement for Dimensional Variations in sand Casting Using Quality Control Tools	Int. Journal of Innovative Research in Science, Engg. & Tech., Aug. 2015	Abhijeet B. Vante G.R.Naik	It is discussed that quality control tools and Quality standards such as KAIZEN, 7QC TOOLS, and TPM etc .for reducing rejection rate of castings and thus improving quality of casting by better control is important.

III. ANALYSIS OF VARIOUS SAND CASTING DEFECTS AND ITS DESCRIPTION

In green sand casting process, if process and process parameters are not controlled properly, numerous defects may occur. Some of these defects are summarised in Table no.2 elaborating pictorial view of defect, its appearance for indentifying a type of defect and various causes of occurring defect.

Table no.2 Cause and short description of sand casting defects

DEFECT TYPE	IMAGE OF DEFECT	SHORT DESCRIPTION OF DEFECT	CAUSE OF DEFECT
Axial shrinkage		A cavity in the middle of casting.	▪ Metal at the centre takes longer time to freeze than the metal surrounding. ▪ Section thickness designed into the casting, ▪ Pouring temperature. ▪ Improper riser design and pouring speed.
Blow hole		Smooth, round holes. They occur in cluster or there may be one large smooth depression. Entrapped bubbles of gas with smooth walls.	▪ Excess moisture in molding the sand. ▪ Low permeability and excessive fine grain sands. ▪ Rusted and damp chills, chaplets and inserts. ▪ Excessive moisture absorption by the cores. ▪ Cores neither properly baked nor adequately vented. ▪ Presence of gas producing ingredients in the mold or core sands. ▪ Moisture content of sand too high. ▪ Extra hard rammed sands. ▪ Molds being not adequately vented. ▪ Excessive release of gas from core. ▪ Inadequate core venting. ▪ Low gas permeability of the core and clay-bonded sand. ▪ Bentonite content too high.
Broken casting		Fractured dimensions at gates, vents, thin sections etc.	▪ Thin neck dimension. ▪ Improper handling and fettling at neck region.

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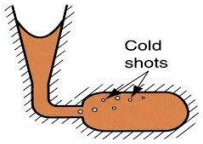
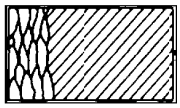
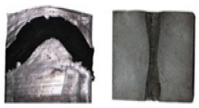
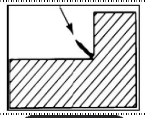
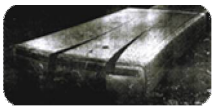
DEFECT TYPE	IMAGE OF DEFECT	SHORT DESCRIPTION OF DEFECT	CAUSE OF DEFECT
Casting chilling defects		The surface of the castings is extremely white, shiny and smooth. The castings is fragile and crispy	▪ Prematurely knock out of sand molds.
Cold Shot (Shot Metal)		Casting has spherical particles coated with oxide inside it. The particles are the same chemical composition as the base metal.	▪ Wrong pouring practices. ▪ Improper runners and risers.
Cold shut		Two metallic streams do not fuse together.	▪ Too cold molten metal. ▪ Too thin casting section. ▪ Too small gates and less gate junctions. ▪ Too many restrictions in the gating system. ▪ Low metal fluidity.
Conchoidal or “rock candy” fracture		Castings fractures and reveals smooth, slightly curved facets on the fracture face.	▪ Elevated aluminum and nitrogen levels.
Core shift		Sidewise displacement of core from its seat	▪ Insufficient size of core prints. ▪ Failure to provide core lock or register. ▪ Shifting of complicated cores during closing or under impact of liquid metal during pouring.
Corner shrinkage		Porosity occurs at hot spots inside the casting or at internal corners	▪ Lack of feed metal to compensate for volumetric contraction during solidification.
Cut or wash		Projection on the drag face of a casting that extends along the surface	▪ Insufficient hot strength. ▪ Too much metal is made to flow through one gate into the mold cavity.
Dispersed shrinkage		Upon machining, small, narrow cavities appear on your casting faces.	▪ Low carbon content or high nitrogen content in the melt.
Fillet vein		A protrusion of metal is sticking out of a 90-degree corner of one of your castings.	▪ Too much binder in the sand causes a crevice to form in a mold or core.
Flash/ fin		Any unwanted, excess metal comes out of the die / mold.	▪ A gap between the cope and drag. ▪ Hydrostatic pressure of the molten metal. ▪ Improper molding box clamping.
Hot tear		A crack on casting surface usually near a thick (hot, weak) section	▪ Resistance of a hard mold or core to casting contraction. ▪ Sharp corners on pattern. ▪ Hard ramming

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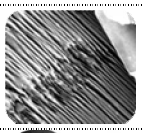
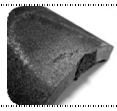
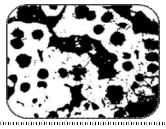
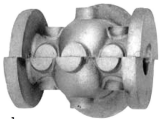
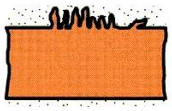
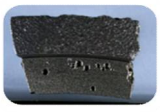
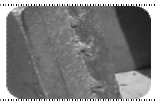
Ingate shrinkage		Porosity occurs at hot spots inside the casting at ingate portion of gating system	▪ Improper location of ingate. ▪ Improper neck modulus. ▪ Too thin neck.
Internal shrink.		Depression or an internal void in a casting	▪ Too cold metal. ▪ Improper feeder and riser design.
Internal sweating/ cold short		Iron beans in the castings.	▪ Unreasonable gating design.
Kish graphite inclusions		Coarse (not smooth) porosity, filled with graphite. It generally becomes visible upon casting machining.	▪ Excessive carbon equivalent in the melt. ▪ Slow cooling. ▪ Differences in section thickness.
Lustrous carbon		Folded, shiny films in its walls.	▪ When materials from mold/core additives and binders volatize, decompose and become entrained in the melt.
Massive free carbide.		Mass free carbide, which will cause fragile, poor welding property to ductile iron castings	▪ Inverse chilling defects. ▪ Poor inoculation.
Micro porosity		Small gas holes either at the surface or just below the surface or fairly uniformly dispersed over the surface	▪ Lack of degassing. ▪ Turbulent metal flow. ▪ Air aspiration.
Mismatch		Dislocation at the parting line.	▪ The cope and drag parts of the mould not remaining in their proper position. ▪ Loose box pins, inaccurate pattern dowel pins or carelessness in placing the cope on the drag.
Misrun		Incomplete cavity filling.	▪ Inadequate metal supply. ▪ Too-low mould or melt temperature. ▪ Improperly designed gates length to thickness ratio of the casting is too large. ▪ Loss of its fluidity.
Penetration		A strong crust of fused sand on the surface of a casting	▪ Insufficient refractoriness of molding materials. ▪ A large content of impurities. ▪ Inadequate mould packing. ▪ High metal fluidity. ▪ Poor quality of mould washes.
Pinholes		Smooth-walled, rounded cavities of various sizes clumped together in one area.	▪ Lack of core and mold venting. ▪ Low sand permeability. ▪ Turbulence during pouring. ▪ Air aspiration. ▪ Gas entrapment.
Sand burning		Thin sand crusts firmly adhering to the casting.	▪ The defect occurs to a greater extent in the case of thick- walled castings. ▪ High temperatures of molten metal.

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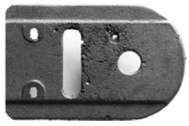
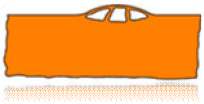
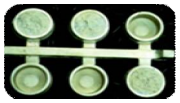
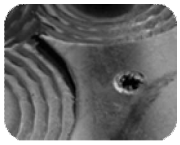
DEFECT TYPE	IMAGE OF DEFECT	SHORT DESCRIPTION OF DEFECT	CAUSE OF DEFECT
Sand drop/ sand crush.		Sand mold drops part of sand blocks, so they will cause the similar shaped sand holes	▪ Low green compressive strength. ▪ Less addition of binders. ▪ High velocity of metal flow. ▪ Pressurized gating system.
Sand inclusion		Irregularly formed sand inclusions, close to the casting surface, combined with metallic protuberances at other points.	▪ Break-up of mould sections during stripping of patterns, core setting. ▪ Uneven compaction of moulds. ▪ Low compactability. ▪ Bentonite content too low, ▪ High content of lustrous carbon producer ▪ Pouring rate too high
Scab		Portion of the face of a mould lifts or breaks down and the recess thus made is filled by metal.	▪ Too fine sand, ▪ Low permeability of sand, ▪ High moisture content of sand. ▪ Uneven moulds ramming.
Seams or scars		Scars are shallow blows.	▪ Improper permeability or venting.
Shrinkage		An internal void in a casting that results from the volume contraction that occurs during solidification.	▪ Improper shrinkage allowance . ▪ Feed metal is not available to compensate for shrinkage as the metal solidifies. ▪ Improper size and location of feeder
Sink mark		Depressions on the surface of a molded part.	▪ Localized shrinkage of the material at thick sections.
Slag Inclusions		Small, gray-green, superficial cavities in the form of droplets or shallow spots appear on your iron castings.	▪ Lack of metal filtration. ▪ Oxide content of the charge too high. ▪ High impurity levels of oxides and hydroxides in charge materials. ▪ Casting temperature too low and pouring rate too slow. ▪ Proportion of inert dust too high.
Sticker.		Sand sticks to the pattern, as the pattern is drawn from the mold.	▪ Lack of proper draft angle. ▪ Sand with a low green tensile strength is used.
Swell		Enlargement of the mold cavity due to molten metal pressure on the mold walls and the sides.	▪ Soft ramming. ▪ Insufficient weighting of the molding boxes during casting. ▪ Low strength of mold. ▪ Mold being not adequately supported.
Uneven hardness		Uneven hardness on the same surfaces. During machining to harder positions, the machining will become more difficult.	▪ Formation of steam bubbles during cooling. ▪ Casting not agitated during quenching.

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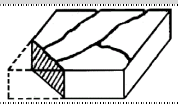
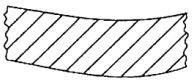
Veining		Lines of extra metal that look like veins appear on your casting surface.	▪ Improperly dried mold. ▪ Temperature too high in kiln. ▪ Heating curve too rapid.
Warped Casting/ Distortion		Casting has bent out of specification.	▪ Residual stresses. ▪ Improper distortion allowance on pattern.

IV. CONCLUSION

Upon surveying a medium scale foundry, it was noticed that the foundry had not standardized its production processes in different areas. In this review several casting defects and their occurrence cause were identified. This will help in analysing the defect and remedies to overcome them. Casting Rejection on the basis of the casting defects should be as minimum as possible for improved quality. One can continuously control rejections by taking in to consideration different parameters at every stage of production. Therefore it is essential for a metal caster to have knowledge on the identification of type of defect and be able to identify the exact root cause, and their remedies. Hence this systematic work will be fruitful for quality casting manufacturing.

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BIOGRAPHY

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Assistant Professor, M.E. (Mechanical Production Engg.), B.E. (Production Engg.), Department of Production Engineering, KIT's College of Engineering, Kolhapur.
(Academic experience 6 Years) Area of expertise: Material science and Casting simulation